U. S. Steel
Clairton Works
400 State Street
Clairton, PA 15025-1855

February 8, 2001

Mr. James W Hagedorn
US EPA Region III
Air Protection Division
3AP13
1650 Arch Street
Philadelphia, PA 19103-2029

Dear Jim,

Please find the attached Pushing Emission Control fan development report from Robinson Industries. The report fills your request for information on this project that you asked for on your December 12, 2000 visit to the plant. Development work was performed on full size models as can be seen from pictures in the report. Robinson Industries at the request and expense of US Steel Clairton Works performed the new fan design development.

The compliance test for the new fans showed a mass emission rate of 0.0044, 0.0040, and 0.0041 grains/ dry standard cubic foot respectively for each of the three test days against the regulatory limit of 0.01gr/dscf. A reduction in fugitive emissions of 40 tons per year is expected.

Flow tests were made once the new fans were installed. The tests showed a flow rate of 135,000 scfm for the new fans Vs measured flow rate of 91,000 scfm to 96,000 scfm for the old fans, a 30% increase in flow.

Please call me at 412-233-1467 if you have any other further questions.

Sincerely

W. C. Graeser

W. C. Graeser

America's Steel Most Recycled Material

ROBINSON INDUSTRIES, INC. INDUSTRIAL FANS • BLOWERS • EXHAUSTERS • SINCE 1892
P.O. BOX 100 ZELIENOPLE, PENNA 16063
PHONE: 724/452-6121 FAX: 724/452-0388

February 23, 2000

Mr. Ray Boronyak
Process Manager – Plant Engineering
U.S. Steel Group – Clairton Works
400 State Street
Clairton, PA 15025

Subject: Laboratory Prototype Test Results & Summary – Baghouse I.D. Fan Upgrade Project - Battery #15, 16

Refer: 44-1/2" x 7-9/16" Robinson Type FRD Fans, Arr.#7, 1780 RPM Originally Supplied to Belco Pollution Control – Robinson F.O.# 76702-3

Mr. Boronyak:

Prototype development and testing has been completed on the subject fans for the Baghouse I.D. fan upgrade project. All air performance testing was completed in Robinson's AMCA accredited laboratory in strict accordance with AMCA Standard 210-85, "Laboratory Methods of Testing Fans for Rating". Please refer to Figures 1 and 2 (end of report) illustrating the prototype test set-up.

The purpose of the testing was to achieve maximum fan static pressure capability of the fan units, while utilizing the existing motors on the fans. Due to the rather low efficiency of the original fans, it was determined that it would not be possible to achieve the desired fan static pressure of 35 In-H_20 at 29,125 CFM (70^oF and 0.0686 Lb/Ft^3) without changing the wheel to a higher efficiency design.

Prototype testing was completed with a new backward curved (BC) wheel design with a new inlet piece and fan housing cut-off modification in order to maximize fan static pressure and efficiency in the original housing. The existing 200 hp, 1780 RPM motors will be able to be re-used with the new design changes. An automated motor amperage based control system to position the fan inlet dampers will be necessary to limit motor horsepower to acceptable levels while running the fans at ambient (cold) conditions.

<u>Prototype Air Performance Testing:</u>

Figure 3 (end of report) shows a fan performance summary for the subject test campaign. From this summary, it may be determined that Test# T-FR-P-11 was the most efficient design from the entire fan performance summary.

Table 1 (below) shows a comparison between the original 44-1/2" x 7-9/16" FRD type fan design (Test# T-FR-P-1) and the final 54" x 7-1/2" BC0926 type fan design along the parabolic system resistance curve. All performance data are corrected to full size and speed and are shown at ambient conditions of 70°F and 0.0686 Lb/Ft^3 inlet density.

Table 1: Fan Performance Comparison – Original vs. New Proposed Design

Fan Test / Description:	Volume (CFM)	Fan Ps (In-H20)	Fan Brake Horsepower	% Static Efficiency
Test# T-FR-P-1 Existing Design: 44-1/2" FRD	24,660	27.8	164	65.5
Test# T-FR-P-11 New Design: 54" BC0926	28,945	34.8	215	73.7

From the comparison of the two tests, an increase in static efficiency of 12.5% (or 8.2 efficiency points) was realized with the new design compared to the existing fan design.

Figures 4 and 5 (attached) are fan performance comparison curves that provide a graphical representation of the results presented above. Figure 4 compares the results of the two tests in addition to showing system resistance curves for both four fan and five fan operation. Performance data points are labeled for the new design at the required operating conditions. Figure 5 shows the same results, but corrected to the normal minimum operating temperature of 105°F and 0.0647 Lb/Ft^3 fan inlet density.

Figure 6 (attached) shows a series of fan performance curves for the new design over a range of temperatures. Results from Test# T-FR-P-11 are shown for temperatures of 120°F, 150°F, 200°F, and 250°F. These temperatures represent the entire range of operating temperatures for the subject fan application. Four and five fan system resistance curves have again been included for reference.

Finally, Figure 7 shows an alternate fan performance curve for a 53-1/2" x 7-1/2" BC0926 fan design. The slightly smaller wheel diameter would result in a decrease in the required fan brake horsepower (i.e. 197 BHP vs. 202 BHP). In addition, if the system were able to tolerate a slight reduction in static pressure available from the fan, the change in system resistance would allow the fan to operate at the required volume of 29,125 CFM. Thus the fan would be able to provide the required volume for gas cleaning and remain under the 200 horsepower motor limitation.

Prototype Sound Testing:

Sound testing was also conducted on the subject fan units in order to determine the effects on sound pressure levels generated from the new BC fan design.

Please note that all sound testing was conducted at Robinson's discretion to insure the change in the sound characteristics of the fan unit would be known and quantified for U.S.S. Clairton personnel. Sound testing was not specified in the original scope of prototype testing.

Figure 8 (attached) shows comparative full octave band sound pressure level data for the prototype fan unit. From the comparison of the two tests (conducted at 1000 RPM) there was a marginal difference in the overall sound pressure level readings taken at three feet from the fan unit. The overall sound pressure level was determined to be 90.3 dBA for the existing FRD fan. A sound pressure level of 89.7 dBA was measured for the new, larger BC fan. The very slight reduction in the sound pressure level of the new design may be explained by the large increase in fan aerodynamic efficiency.

For a more thorough analysis of the sound characteristics between the existing and new designs, narrow band, FFT sound pressure level data was measured and also compared. Figure 9 (attached) shows the narrow band sound pressure level comparison for the two fan units. From the narrow band data, it is evident that an increase in tonal noise is generated from the fan unit at the blade passage frequency (BPF) as well as second, third, and fourth harmonics. By identifying these individual discreet frequencies it may be determined that the new BC fan design will generate more annoying tonal noise than the original fan, although the overall 'A' weighted sound pressure level (full octave band dBA) will remain relatively constant.

Conclusions:

Based on the completed prototype test campaign conducted at Robinson Industries, the following conclusions may be determined:

1. The desired fan performance for both four fan and five fan operation was achieved (within 1% on volume and pressure) with the new BC0926 design fan rotor, new design inlet (spinning) piece, and fan housing cut-off modification.

2. Fan static efficiency was increased by 8.2 points (or 12.5%) from 65.5% to 73.7%. This increase in efficiency will allow the existing 200 hp motors to be re-used with the new design changes.

3. The shape of the fan performance characteristic curve was favorably altered with the new fan design. The downward sloping portion of the new design fan curve has a steeper slope and begins at a lower volume flowrate. Therefore, the rating points for both four fan and five fan operation were determined to be located on a stable (surge free) range of the fan performance curve.

U.S.S. Clairton – Baghouse I.D. Fan Prototype Testing
February 23, 2000

4. Overall 'A' weighted full octave band sound pressure level measured during prototype testing was determined to be very close for both the new and existing fan designs. However, the discreet frequency tonal noise generated at the blade passage frequency and subsequent harmonics were determined to be much higher than the original levels, thus causing the fan to sound more annoying to an observer. The increase in the overall non-weighted sound pressure level in this frequency range (80 Hz–625 Hz) was determined to be approximately 4.6 dB.

5. If the full 35 In-H_2O (at 70°F and 0.0686 Lb/Ft^3 density) is not required, the new fan design may be slightly undersized to 53-1/2" Dia. This would allow the fan to operate at the full rated volume of 29,125 CFM and remain under200 horsepower (197 actual hp). This is an option, and is dependent on the exact system pressure requirement as determined by S/D Engineers, Inc.

Recommendations:

Based on the completed prototype test campaign conducted at Robinson Industries, the following action is recommended:

1. Robinson Industries to supply five (5) new complete retro-fit packages including: 54" x 7-1/2" BC0926 fan rotor (complete with new shaft), new inlet (spinning) piece, and new housing cutoff assembly.

2. The larger weight and thrust load resulting from the new rotor substantially lowers the L_{10} life of the existing 2-7/16" drive side spherical roller bearing. Bearing analyses have been completed by Robinson and sent to U.S.S. - Clairton Works for review. Due to the marginal life of the existing bearing with the new rotor design, U.S.S. may wish to modify the inboard bearing pedestal to allow for a 2-15/16" bearing in order to provide a more satisfactory L_{10} life.

3. All field site work including modification of the fan housing cutoffs, installation of the new rotors and inlet pieces, and modification of the bearing pedestals should be supervised by Robinson field service personnel. In addition, all start-up services including bearing inspection and coupling alignment may be completed or supervised by Robinson field service personnel. Please contact Robinson's field service coordinator, Ed Weiss, at (724) 452-6121 Ext. 173 if you have any specific service related questions.

All pricing information for the subject modifications and retro-fit package will be handled through Robinson's Repair Department Manager, Tim Rape. Please feel free to contact Tim at (724) 452-6121 Ext. 113 regarding any pricing or delivery questions you may have on the subject fans.

Robinson Industries continues to look forward to working with U.S.S. - Clairton Works as a valued customer. Should you have any questions or comments regarding the subject test report and recommendations for the baghouse I.D. fan upgrade project, please feel free to contact me directly at (724) 453-7403 or via e-mail at dgrupp@robinsonfans.com.

DRG

Very Truly Yours,

Att : Figures 1 through 9

xc: Les Gutzwiller
Dom Codispot
Tom Kuli
Tim Rape
Ed Weiss
Dan Banyay
Sam Toas
Rich King
Bob Albert – S/D Engineers, Inc.

ROBINSON INDUSTRIES, INC.

D.R.G.

David R. Grupp
Director of Research

Figure 1: Prototype Fan Setup – Robinson Laboratory

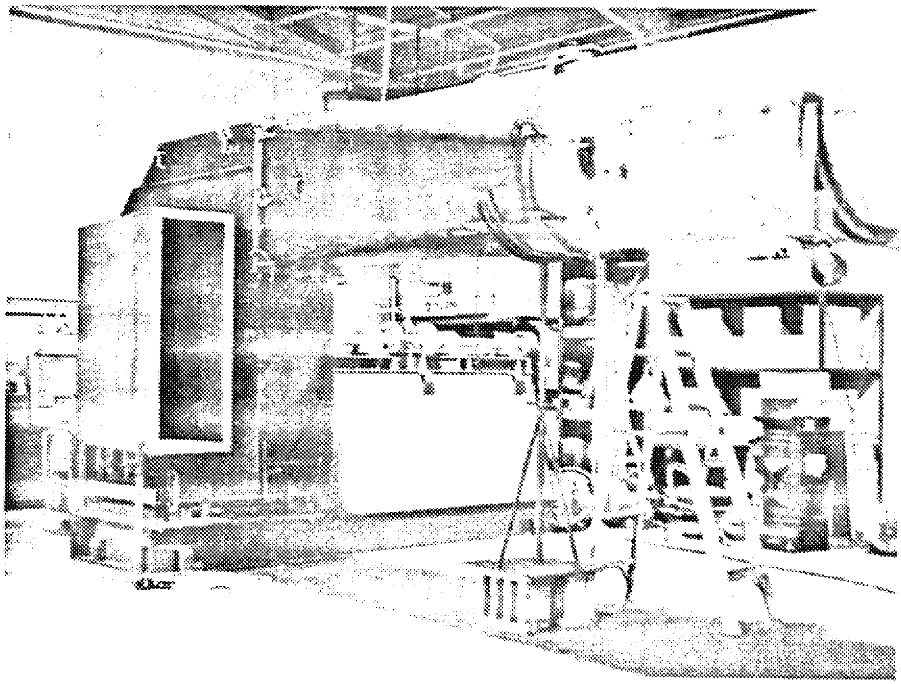


Figure 2: AMCA Std. 210-85 Air Performance Setup

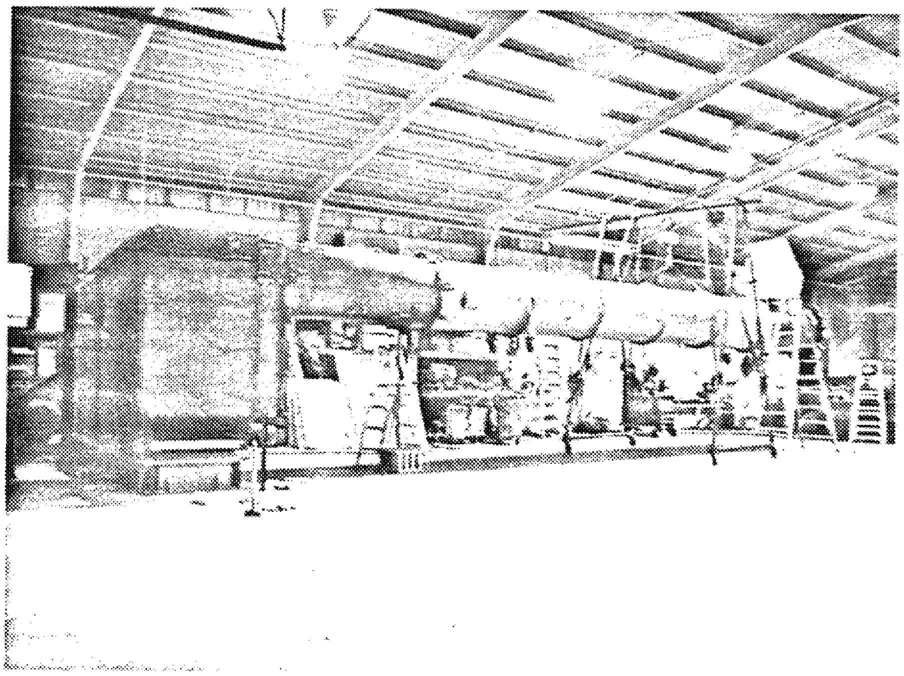


FIGURE 3: PROTOTYPE TEST SUMMARY

U.S.S. CLAIRTON WORKS LABORATORY PROTOYPE TESTING

ROBINSON INDUSTRIES, INC.

DEVELOPMENT OF HIGH EFFICIENCY BACKWARD CURVED (BC) DESIGN
FOR: BAGHOUSE I.D. FAN UPGRADE PROJECT

Updated 2/14/2000 DRG

TEST SERIES: T-FR-P ROBINSON TEST F.O.# 99412

TEST NUMBER	DESCRIPTION	Fan Inlet Vol. (CFM)	Fan Ps (In-H2O)	Brake Horsepower	% Static Efficiency	Fan Inlet Temp (°F)	Fan Inlet Density
Original Design:	Original 44-1/2" x 7-9/16" FRD Robinson Fan Design	31400	18.00	116	76.6	250	0.0534
New Design:	To Be Determined	29125	35.00	200	80.1	70	0.0686
T-FR-P-1	44-1/2" x 7-9/16" FRD Robinson Fan w/ Inlet Box, Splitter Plate Assembled	29125	26.44	184	65.7	70	0.0750
T-FR-P-2	44-1/2" x 7-9/16" FRD Robinson Fan - Removed Inlet Box, Splitter Plate	29125	27.56	183	69.1	70	0.0750
T-FR-P-3	Bearing Horsepower Drag Test - Torquemeter Bearings			2.90			
T-FR-P-4	47-1/4" x 7-9/16" Tipped Out FRD Fan - Removed Inlet Box, Splitter Plate	29125	35.10	229	70.0	70	0.0750
T-FR-P-5	47-1/4" x 7-9/16" Tipped Out FRD Fan - w/ Inlet Box, Splitter Plate Installed	29125	34.00	227	68.5	70	0.0750
T-FR-P-6	54" x 7-1/2" BC0926 Wheel and Inlet ReDesign w/ Inlet Box, Splitter Installed	29125	36.40	237	70.4	70	0.0750
T-FR-P-7 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Inlet Contoured	28610	37.31	233	71.9	70	0.0750
T-FR-P-8 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Add'l. Inlet Contour	28740	37.42	233	72.6	70	0.0750
T-FR-P-9 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Reduced Radial Clr.	Wheel	Locator	Test			
T-FR-P-10 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Reduced Radial Clr.	28860	37.83	235	72.9	70	0.0750
T-FR-P-11 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Modified Cutoff Loc.	28945	38.02	235	73.7	70	0.0750
FAN STATIC PRESSURE CRITERIA: 70°F, 0.0686 LB/FT³							
T-FR-P-1	44-1/2" x 7-9/16" FRD Robinson Fan w/ Inlet Box, Splitter Plate Assembled	29125	24.16	169	65.7	70	0.0686
T-FR-P-5	47-1/4" x 7-9/16" Tipped Out FRD Fan - w/ Inlet Box, Splitter Plate Installed	29125	31.10	208	68.5	70	0.0686
T-FR-P-6	54" x 7-1/2" BC0926 Wheel and Inlet ReDesign w/ Inlet Box, Splitter Installed	29125	33.29	217	70.4	70	0.0686
T-FR-P-7 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Inlet Contoured	28610	34.13	213	71.9	70	0.0686
T-FR-P-8 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Add'l. Inlet Contour	28740	34.23	213	72.6	70	0.0686
T-FR-P-9 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Reduced Radial Clr.	Wheel	Locator	Test			
T-FR-P-10 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Reduced Radial Clr.	28860	34.60	215	72.9	70	0.0686
T-FR-P-11 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Modified Cutoff Loc.	28945	34.78	215	73.7	70	0.0686
FAN BRAKE HORSEPOWER CRITERIA: 105°F, 0.0647 LB/FT³							
T-FR-P-1	44-1/2" x 7-9/16" FRD Robinson Fan w/ Inlet Box, Splitter Plate Assembled	29125	22.81	159	65.7	105	0.0647
T-FR-P-5	47-1/4" x 7-9/16" Tipped Out FRD Fan - w/ Inlet Box, Splitter Plate Installed	29125	29.33	196	68.5	105	0.0647
T-FR-P-6	54" x 7-1/2" BC0926 Wheel and Inlet ReDesign w/ Inlet Box, Splitter Installed	29125	31.40	204	70.4	105	0.0647
T-FR-P-7 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Inlet Contoured	28610	32.19	201	71.9	105	0.0647
T-FR-P-8 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Add'l. Inlet Contour	28740	32.28	201	72.6	105	0.0647
T-FR-P-9 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Reduced Radial Clr.	Wheel	Locator	Test			
T-FR-P-10 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Reduced Radial Clr.	28860	32.63	203	72.9	105	0.0647
T-FR-P-11 *	54" x 7-1/2" BC0926 Wheel & Inlet ReDesign w/ Box, - Modified Cutoff Loc.	28945	32.80	202	73.7	105	0.0647

* Note: Fan Performance for Test# T-FR-P-7 and up are shown at Actual Volume along Rated Parabolic System Resistance Curve.

Density Calculations:

@ 70 Deg. F, Fan Static Pressure of 35 In-H20; Density = 0.075 * (407.7-35.0) / 407.7 = 0.0686 LB/FT3
@ 105 Deg. F, Fan Static Pressure of 32.8 In-H20; Density = 0.075 * (70+459.7) / (105+459.7) * (407.7-32.8) / 407.7 = 0.0647 LB/FT3

ROBINSON INDUSTRIES INC.
FAN: 54 X 7.5 - SWSI
TEST #: T-CLAIRTN3

SPEED : 1780 RPM
TEMP : 70 DEG. F
DENSITY: .0686 #/FT3

DATE: 2-17-2000
CURVE OVERLAY PROGRAM
COMPLETED BY: DRG

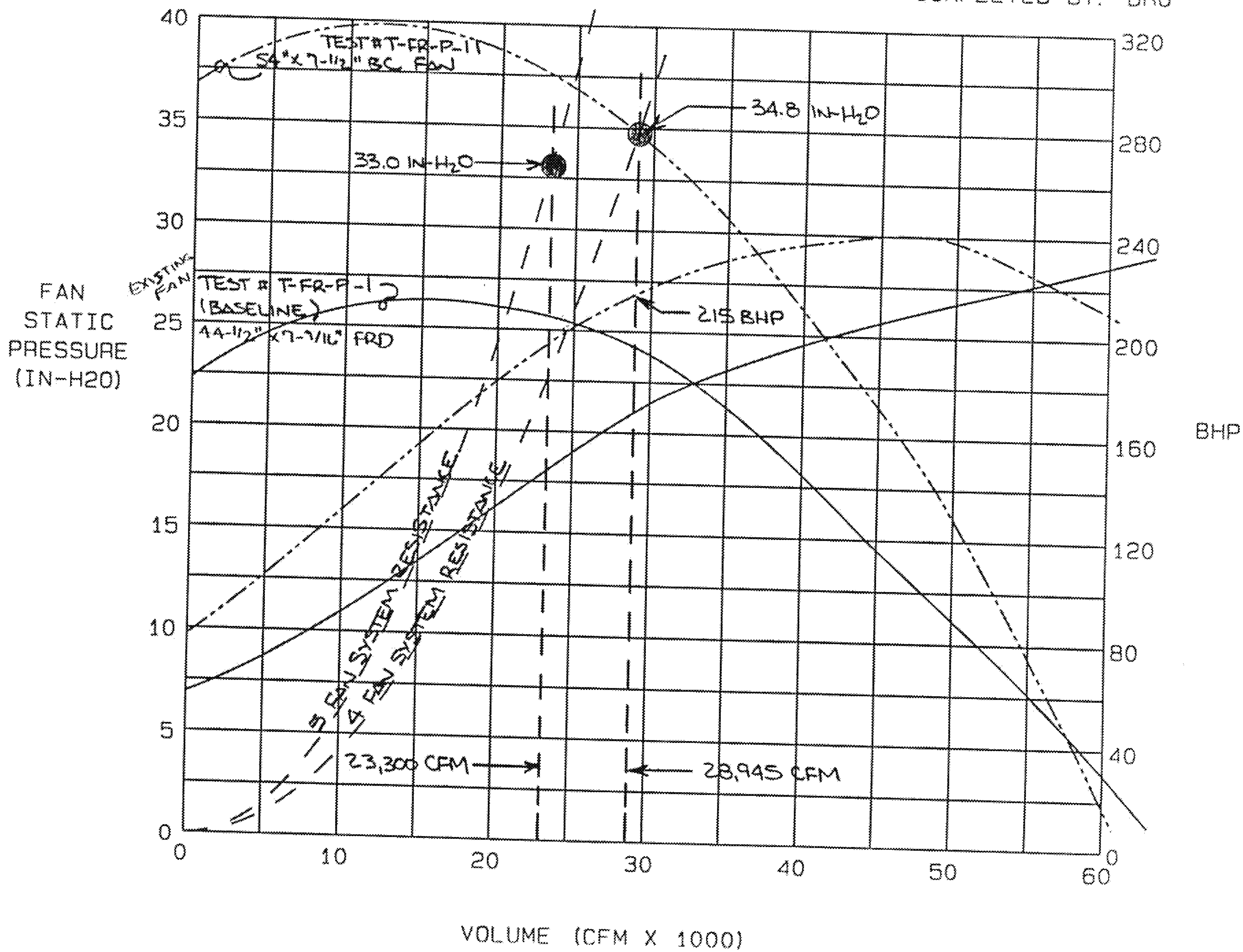


FIGURE 4

ROBINSON INDUSTRIES INC.
FAN: 54 X 7.5 - SWSI
TEST #: T-CLAIRTN2

SPEED : 1780 RPM
TEMP : 105 DEG. F
DENSITY: .0647 #/FT3

DATE: 2-17-2000
CURVE OVERLAY PROGRAM
COMPLETED BY: DRG

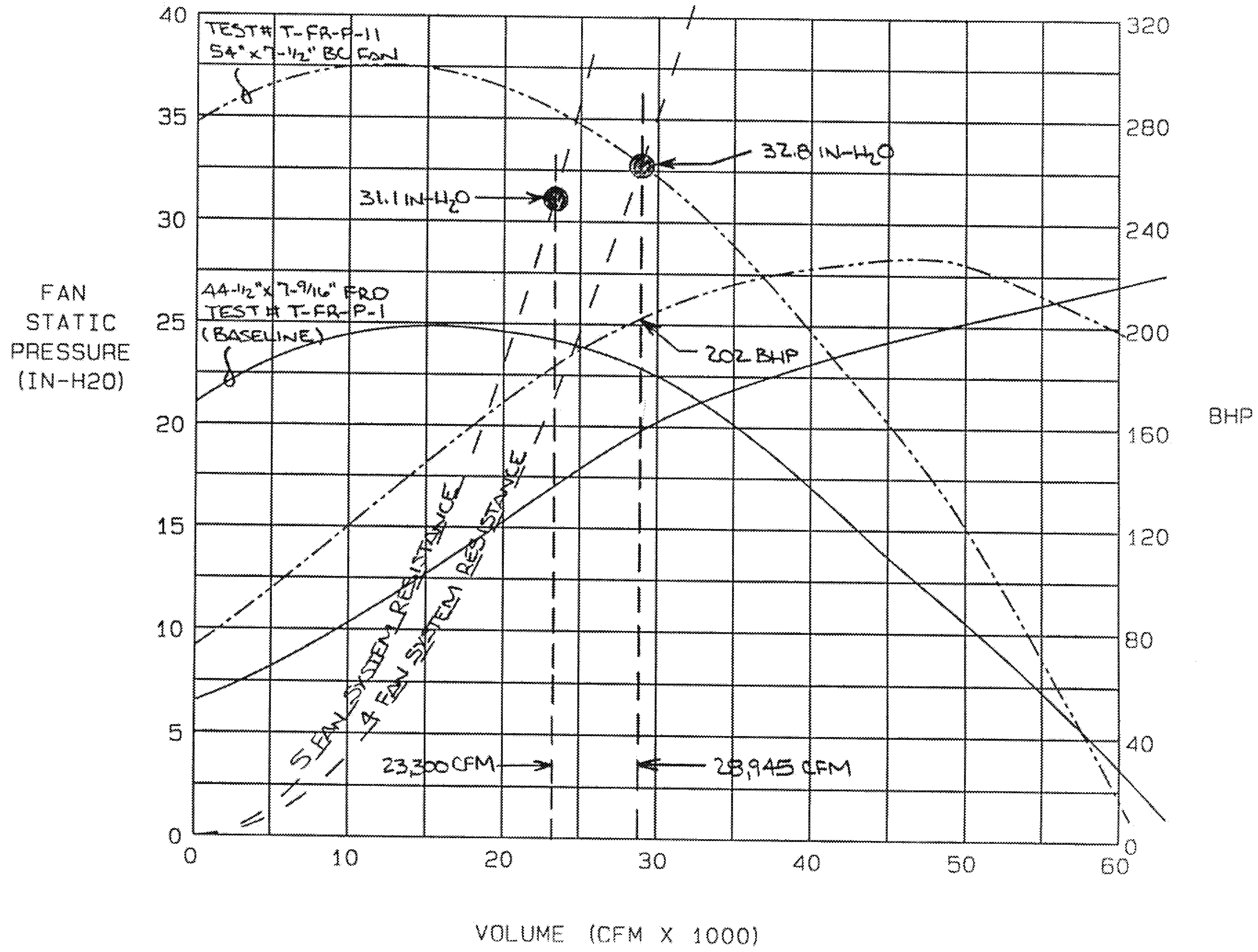


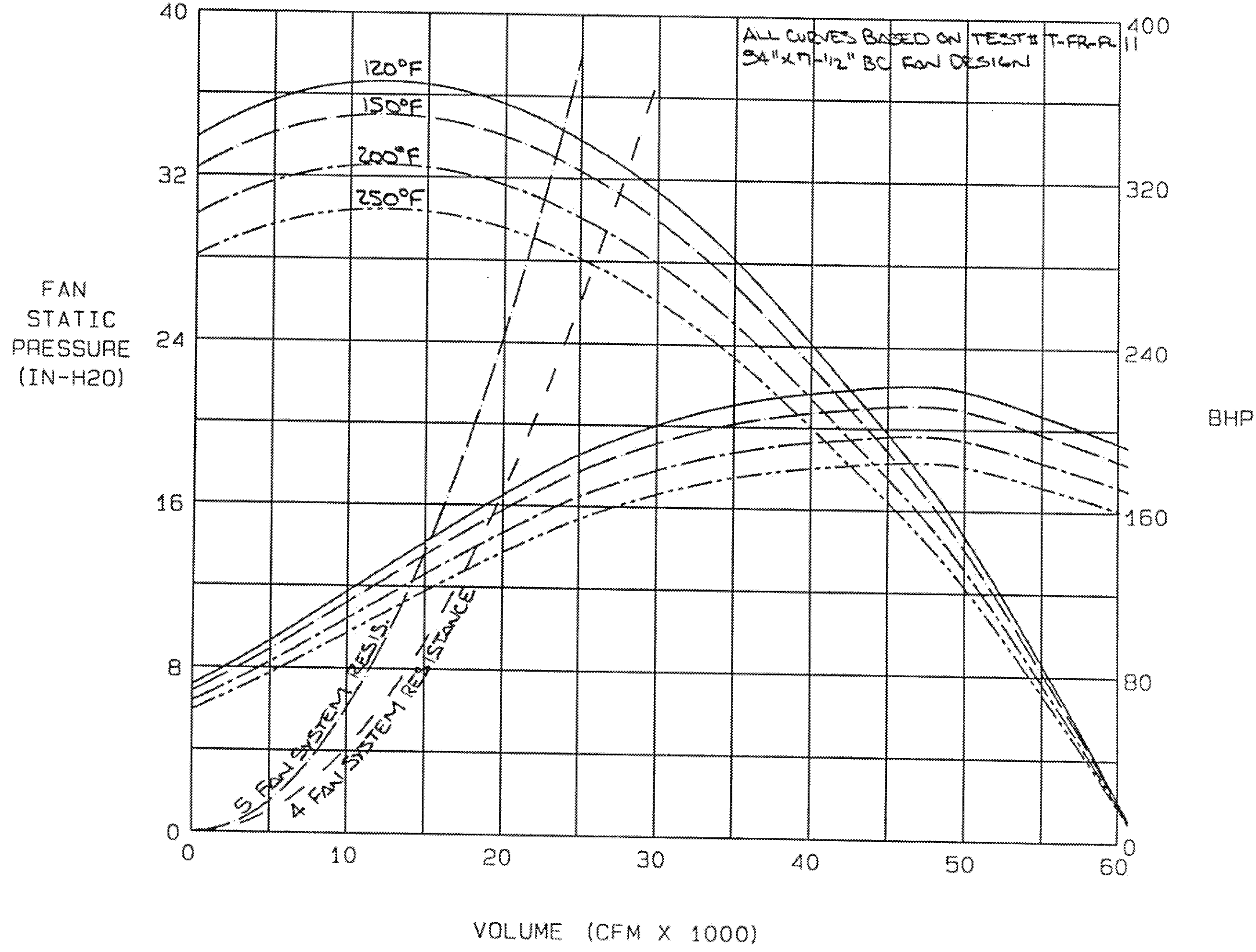
FIGURE 5

FIGURE 6

ROBINSON INDUSTRIES INC.
FAN: 54 X 7.5 - SWSI
TEST #: T-CLAIRTON

SPEED : 1780 RPM
TEMP : 120 DEG. F
DENSITY: .0631 #/FT3

DATE: 2-17-2000
CURVE OVERLAY PROGRAM
COMPLETED BY: DRG



ROBINSON INDUSTRIES INC.
FAN: 53.5 X 7.5 - SWSI
TEST #: T-CLAIRTN2

SPEED : 1780 RPM
TEMP : 105 DEG. F
DENSITY: .0647 #/FT3

DATE: 2-17-2000
CURVE OVERLAY PROGRAM
COMPLETED BY: DRG

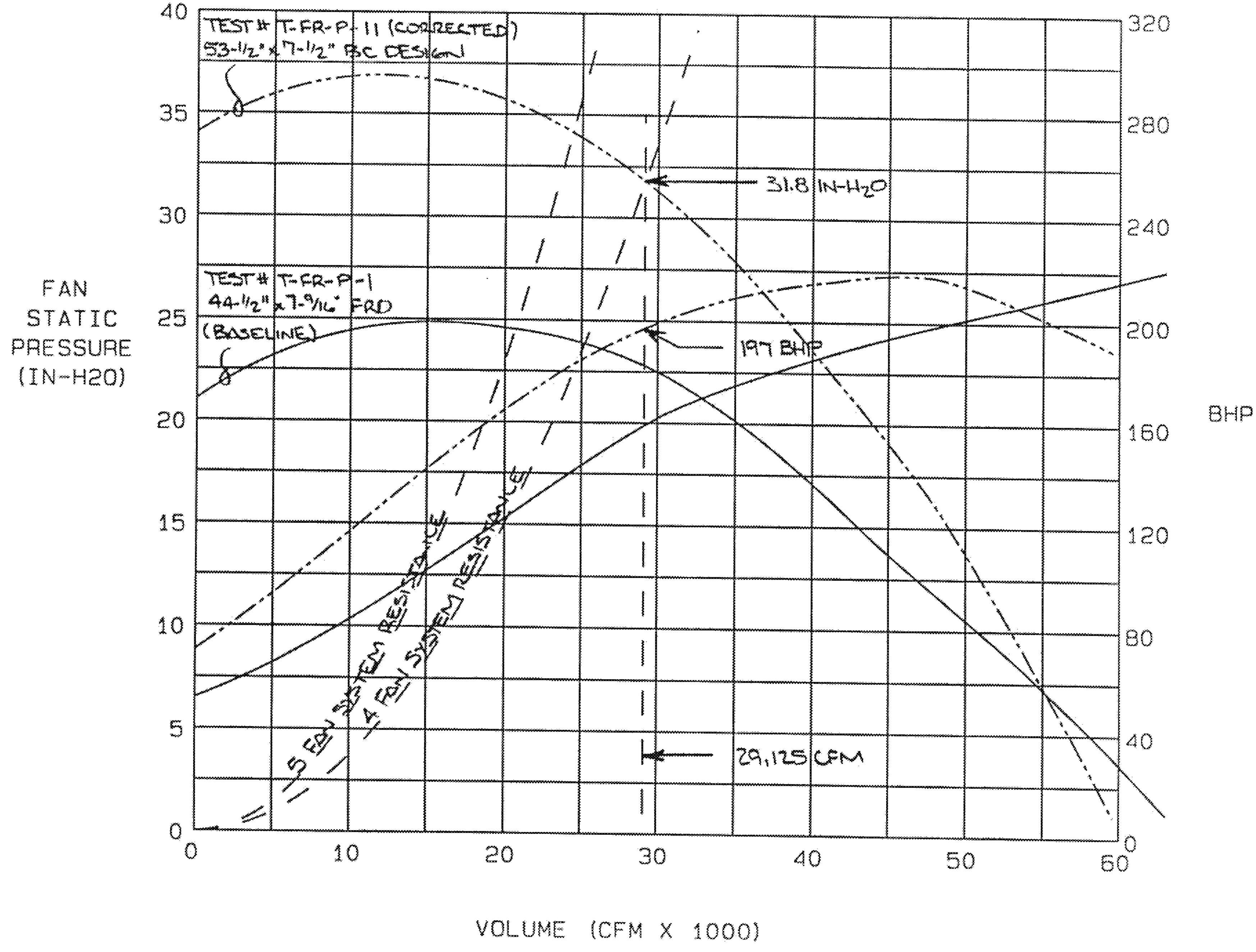


FIGURE 7

Figure 8: Full Octave Band Analysis

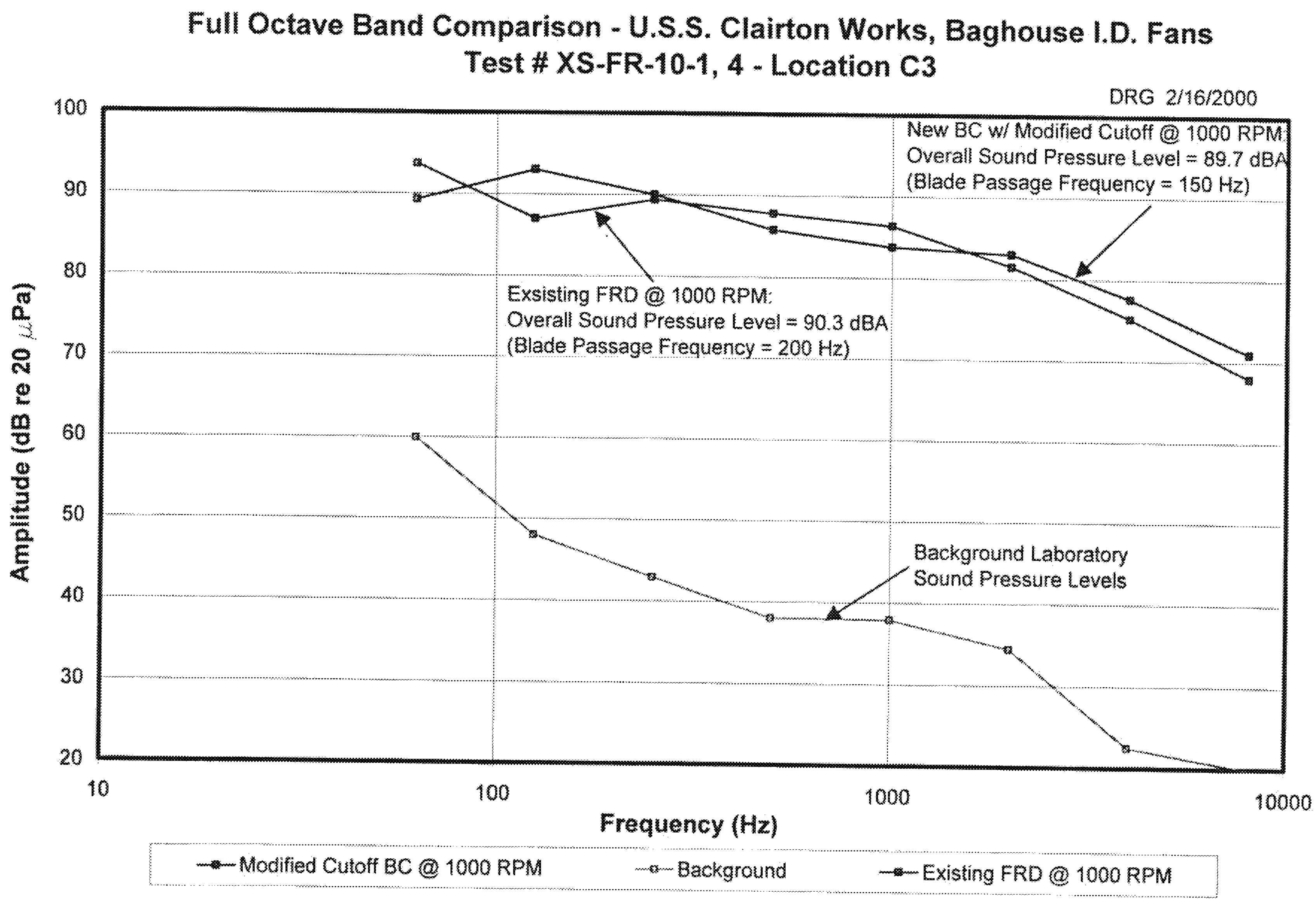


Figure 9: Narrow Band Analysis